Spitzer Observations of Centaurus A

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Centaurus A:

❑ Centaurus A (Cen A) is one of the nearest large radio galaxies, at a distance of 3.4Mpc (Israel 1998).

❑ The optical host galaxy, NGC 5128, is believed to be the result of a merger of a spiral galaxy with a large elliptical galaxy (Baade & Minkowski 1954). Evidence for this includes large dust lanes in its central regions, shell-like features, which are predicted by numerical simulations of mergers (see for example Malin et al. 1983) and tidal features (Peng et al. 2002).

❑Previous studies have investigated the kinematics of the ionized and molecular gas, and studied the infrared (IR) morphology in terms of a recent merger (~200 million years since the core of the spiral galaxy reached the elliptical galaxy nucleus) which has produced a warped, dusty disk.

New Data Sets:

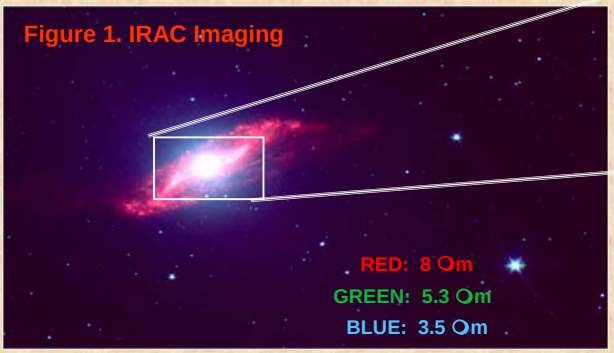
In this project we are now working with new Spitzer data including: **IRAC imaging** in all four bands, **MIPS imaging** in all three bands, **high resolution IRS spectroscopy** at three pointings and a **low resoltuion IRS spectral map**.

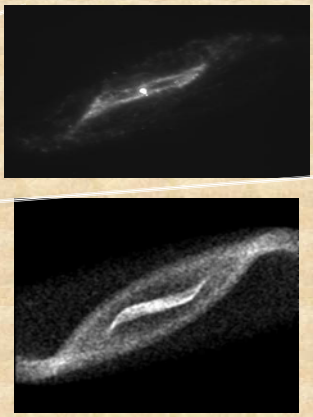
Goals:

❑to image the dusty warped disk in order to understand its structure

❑ to measure the IR flux associated with the inner radio lobes and determine the predominant cause of this emission.

❑ to probe the physics of the inner regions of the galaxy via hi and low resolution IRS spectroscopy and to investigate the relative contributions of the AGN and star-formation.





Modelling the warped disk:

Spitzer IRAC imaging of Centaurus A reveals a parallelogram shaped structure.

When an optically thin warped disk is seen in emission, the edges of folds in the disk correspond to regions of higher surface brightness. Likewise since the morphology is symmetric across the origin (*r* to -*r*) we infer that the dusty disk must be nearly optical thin in the mid-infrared.

A model of emission from a warped disk is produced by considering the disk to compose of a series of tilted rings of different radii. Each ring is described by two angles: a precession angle and an inclination angle. Model images were produced by integrating the emission along the line of sight, through the model disk, beginning with the precession and inclination angles of Quillen et al. (1993) and varying these angles in order to fit the IRAC image 'by eye'.

The Spitzer IRAC images allow us to better study the outer parts of the disk, compared with previous ^{12}CO(2-1) spectra (Quillen at al. 1992). The best matching model to the IRAC morphology was produced by allowing the disk to twist to a greater extent than previously thought. This model predicts that the disk alternates between having the southern and northern side nearest to the observer.

Figure 2. Greyscale: 24 Om MIPS image; Contour: 21cm VLA map

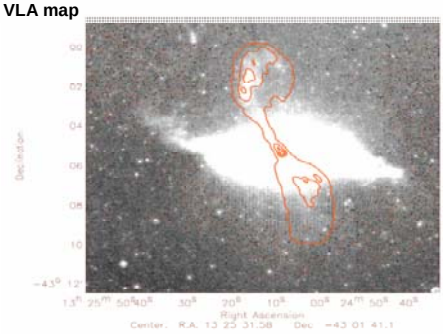


Figure 3. Inner radio lobe detections in each of IRAC bands 1 to 4 (left to right)

Inner Radio Jet Emission

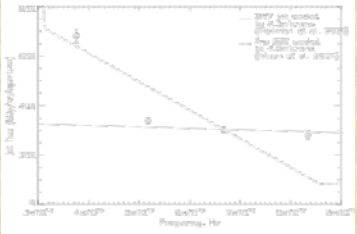
Centaurus A is a Faranoff-Riley Class I radio galaxy at a distance of only 3.4 Mpc. Whilst other radio galaxies have been observed to emit over a greater extent, Centaurus A is still one of the largest known. Its jet have been observed to extend over about 6 degrees in total (see, for example, Burns et al. 1983). Here, however, we focus on the inner lobes which extend 6 arcminutes from the nucleus and are shown, at 21 cm emission, by the orange contours in Figure 2.

The Figure shows the 21cm radio lobes overlaid on the greyscale 24μm MIPS image and clearly shows IR emission associated with the northern inner lobe. The lobe is also detected in all four IRAC bands as shown in Figure 3.

By rotating a jet shaped aperture about the galaxy centre it was possible to estimate the background emission of the galaxy and determine the emission solely due to the jet.

Figure 4 shows the SED of the inner lobe as determined by the Spitzer IRAC and MIPS points. The solid line shows the spectra of the inner jet of M87 (a flat spectrum jet, see Perlman et al. 2000) scaled to the 4.5μm

Figure 4: The IR SED of the inner radio lobe of Cen A

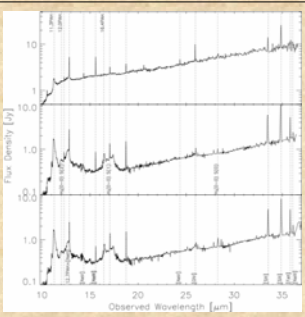


Cen A point. The dashed line shows the spectrum of star-formi ng galaxy Arp 220 (Ivison et al. 2004), also scaled to the 4.5μm point. It is not obvious from the comparison to these sources whether the origin of the IR emission associated with Cen A's inner radio lobe is star-formation or synchrotron emission. However it seems unlikely that stars would produce such a bright feature at 24μm meaning the emission is likely to be non-thermal.

Figure 5: The strength of the 6.2 μm PAH feature (left) and the [NeIII] 15.6 μm emission line (right) as a function of spatial position

Low Resolution IRS Spectral Mapping

Low resolution spectra were taken, using both the short and long modules, with IRS in a grid pattern, covering the inner parallelogram structure. With this data set we may follow the strengths of spectral features as a function of position. The left panel of Figure 5 shows the 6.2 μm Polycyclichyrdocarbon (PAH) feature. PAHs are associated with dust emission, where the dust is irradiated by star-forming regions (REF). In stark contrast the [NeIII] 15.5 μm emission line requires a much higher energy density irradiating field for its production and therefore it's physical association with the nucleus is expected.



High Resolution IRS Spectra

Figure 6: High resolution spectra have been obtained at three points on the source: the nucleus and the extremes of the parallelogram structure. The nuclear spectrum is shown in the top panel of this figure and the 'edge' spectra in the lower two panels. These spectra offer a more powerful analysis of narrow line features which are lost in the low resolution spectra.

Highlights:

Using new Spitzer data from IRAC, MIPS and IRS we investigate the properties of the nearby radio galaxy Centaurus A. The proximity of this galaxy allows us to study its activity in more detail than other, more distant radio galaxies. In addition the host elliptical galaxy has undergone a merger with a spiral galaxy relatively recently resulting in prominent dust lanes and a warped, dusty disk. The morphology of the dusty disk, in particular the striking parallelogram structure, has been used as a guide to modelling the disk as an optically thick, twisted disk. These new data indicate that the disk is more twisted than previously believed and the edge of the disk closest to the observer switches from north to south. IRAC and MIPS imaging have been used to measure the IR emission associate with the inner radio lobe and it has been shown that the origin of this emission is likely to be non-thermal, i.e. this emission is synchrotron and not due to star-forming regions. Low and high resolution spectra have been obtained with IRS and will be used to investigate the variation of physical parameters, such as ionization parameter, as a function of position through the dusty disk.